

PATENT CLAIMS

1 1. A method of producing a strained layer (9) on a
2 substrate (1, 2) with the steps:

3 producing a defect region (7) in a layer (2, 4, 5,
4 11) neighboring a layer (3) to which strain is to be imparted,
5 relaxing at least one layer (4, 11) neighboring the
6 layer (3) to which strain is to be imparted.

1 2. The method according to claim 1 in which dislocations
2 are formed which give rise to relaxation of at least one
3 neighboring layer (4, 11) of the layer (3) which is to be strained.

1 3. The method according to one of the preceding claims
2 characterized in that the layer structure, for relaxation, is
3 subjected to a thermal treatment and/or oxidation.

1 4. A method according to one of the preceding claims
2 characterized in that at least one first layer (4; 11) is deposited
3 upon the layer (3) to be strained.

1 5. The method according to one of the preceding claims
2 characterized in that the first layer (4, 11) has a different
3 degree of stress than the layer (3) to be strained.

1 6. The method according to one of the preceding claims
2 characterized in that the defect region (7) is produced in the
3 first layer (4; 11).

1 7. The method according to one of the preceding claims
2 in which a further relaxing layer is disposed between the substrate
3 (1, 2) and the layer (3) to be strained.

1 8. The method according to one of the preceding claims
2 characterized in that the defect region (7) is produced in the
3 substrate.

1 9. The method according to one of the preceding claims
2 characterized in that the defect region (7) is produced in the
3 layer (3) to be strained itself.

1 10. The method according to one of the preceding claims

2 characterized in that two neighboring layers (11, 13) of the layer
3 (12) to be strained have other degrees of dislocation than the
4 layer (12) to be strained.

1 11. The method according to one of the preceding claims
2 in which a plurality of layers (11, 13) are relaxed.

1 12. The method according to one of the preceding claims
2 in which a plurality of layers (3, 12) to be strained, have strain
3 imparted to them.

1 13. The method according to one of the preceding claims
2 characterized in that on the first layer (4, 11) epitactically at
3 least one further layer (5; 12, 13) with respectively a different
4 lattice structure is deposited.

1 14. The method according to one of the preceding claims
2 characterized in that the defect region (7) is produced in the
3 second layer (5; 13).

1 15. The method according to one of the preceding claims

2 characterized in that on the layer to which strain is to be
3 imparted (3) at least one graded layer is deposited as the first
4 layer (4).

1 16. The method according to one of the preceding claims
2 characterized in that at the region of the layer (3) to be
3 strained, the graded layer (4) has a degree of dislocation which is
4 different from that of the layer (3) to be strained.

1 17. The method according to one of the preceding claims
2 characterized in that a defect region (7) is produced in a graded
3 layer (4).

1 18. The method according to one of the preceding claims
2 in which an epitactic layer structure comprising a plurality of
3 layers is produced on a substrate (1, 2, 3, 4, 5, 11, 12, 13) in a
4 deposition process.

1 19. The method according to one of the preceding claims
2 in which the first layer (4, 11) is relaxed by a thermal treatment.

1 20. The method according to one of the preceding claims
2 characterized in that for the thermal treatment a temperature
3 between 550 degrees and 1200 degrees C is selected.

1 21. The method according to one of the preceding claims
2 characterized in that for the thermal treatment, a temperature
3 between 700 degrees and 980 degrees C is selected.

1 22. A method according to one of the preceding claims
2 characterized in that the thermal treatment is carried out in an
3 inert atmosphere.

1 23. The method according to one of the preceding claims
2 characterized in that the thermal treatment is carried out in a
3 reducing or oxidizing or nitriding atmosphere and especially in
4 nitrogen.

1 24. The method according to one of the preceding claims
2 characterized in that the relaxation is carried out over a limited
3 region of a layer.

1 25. The method according to one of the preceding claims
2 in which a mask (6) is applied.

1 26. The method according to one of the preceding claims
2 characterized in that the defect region (7) is produced by ion
3 implantation.

1 27. The method according to the preceding claim
2 characterized in that for the implantation, hydrogen ions or helium
3 ions are selected.

1 28. The method according to one of the preceding claims
2 characterized in that the hydrogen ions or helium ions are
3 implanted with a dose of 3×10^{15} to $4 \times 10^{16} \text{ cm}^{-2}$, especially with a
4 dose of 0.5×10^{16} to $2.5 \times 10^{16} \text{ cm}^{-2}$.

1 29. The method according to one of the preceding claims
2 characterized in that for the implantation, Si ions are selected.

1 30. The method according to the preceding claim
2 characterized in that Si ions are implanted with a dose of about

3 0.5×10^{14} to 5×10^{14} cm⁻².

1 31. The method according to one of the preceding claims
2 characterized in that for the implantation, carbon ions, nitrogen
3 ions, fluorine ions, boron ions, phosphorous ions, arsenic ions,
4 germanium ions, antimony ions, sulfur ions, neon ions, argon ions,
5 krypton ions and/or xenon ions are selected.

1 32. The method according to one of the preceding claims
2 characterized in that at least two implantations are carried out.

1 33. The method according to one of the preceding claims
2 characterized in that a hydrogen implantation is carried out in
3 combination with a helium implantation.

1 34. The method according to one of the preceding claims
2 characterized in that a boron implantation is carried out in
3 combination with a hydrogen implantation.

1 35. The method according to one of the preceding claims,
2 characterized in that two implantations are carried out to produce

3 two defect regions in the first layer (4) and in the second layer
4 (5).

1 36. The method according to one of the preceding claims
2 characterized in that the wafer during the ion implantation is
3 tilted at an angle greater than 7 degrees, especially at an angle
4 of 30 to 60 degrees.

1 37. The method according to one of the preceding claims
2 characterized in that between two implantations a thermal treatment
3 is carried out.

1 38. The method according to one of the preceding claims
2 characterized in that the defect region (7) is produced by a change
3 in the temperature during the formation of one of the layers (4, 5;
4 11).

1 39. The method according to one of the preceding claims
2 characterized in that the defects are produced in a Si-C layer by
3 thermal treatment.

1 40. The method according to one of the preceding claims
2 characterized in that as the substrate, an amorphous layer,
3 especially of an insulator (2) is selected.

1 41. The method according to one of the preceding claims
2 characterized in that an SOI substrate (1, 2, 3) is chosen as the
3 base structure for the substrate.

1 42. The method according to the preceding claim
2 characterized in that the silicon surface layer (3) of the SOI
3 substrate (1, 2, 3) is the layer (3) to be strained and the SiO₂ of
4 the SOI substrate (1, 2, 3) forms the insulator (2) on the
5 substrate (1).

1 43. The method according to one of the preceding claims
2 characterized in that an SIMOX or BESOI substrate is selected as
3 the base structure for the substrate.

1 44. The method according to one of the preceding claims
2 characterized by selecting a silicon on sapphire as the base
3 structure for a substrate.

1 45. The method according to one of the preceding claims
2 characterized by selecting a substrate that becomes viscous at a
3 temperature required for the relaxation.

1 46. The method according to one of the preceding claims
2 characterized in that SiO₂, glass, SiC, Si-Ge, graphite, diamond,
3 quartz glass, GdGa-garnet, III-V semiconductor and III-V nitride
4 are selected as the material for the substrate (1, 2).

1 47. The method according to one of the preceding claims
2 in which an insulator (2) on a substrate (1) is selected.

1 48. The method according to one of the preceding claims
2 characterized by the selection of Si-Ge or Si-Ge-C or Si-C as the
3 material for the first layer which is disposed on the layer (3) to
4 be strained.

1 49. The method according to one of the preceding claims
2 characterized by the selection of silicon as the material for the
3 layer (3) to be strained.

1 50. The method according to one of the preceding claims
2 characterized by the choice of silicon as the material for the
3 second layer (5) which is disposed upon the first layer (4).

1 51. The method according to one of the preceding claims
2 characterized by the selection of Si-Ge as the material for a
3 graded layer.

1 52. The method according to the preceding claim
2 characterized in that the germanium concentration in the graded
3 layer decreases from the interface with the layer (3) to be
4 strained to the surface of the graded layer.

1 53. The method according to one of the preceding claims
2 characterized in that the germanium concentration in a Si-Ge layer
3 at the interface with the layer (3) to be strained is 100 percent.

1 54. The method according to one of the preceding claims
2 characterized in that the total layer thickness of the layer
3 structure is so selected that during the growth of the applied

4 layers (4; 11, 13) these do not produce any noticeable relaxation.

1 55. The method according to one of the preceding claims
2 characterized in that the dislocation density after the growth
3 amounts to less than 10^5 cm^{-2} .

1 56. The method according to one of the preceding claims,
2 characterized in that a layer (3) to be strained with a thickness
3 d_3 in the range of 1 to 50 nanometers is selected.

1 57. The method according to one of the preceding claims,
2 characterized in that a layer (3) to be strained with a thickness
3 d_3 in the range of 5 to 30 nanometers is selected.

1 58. The method according to one of the preceding claims,
2 characterized in that a first layer (4) with a thickness d_4 close
3 to the critical layer thickness is selected.

1 59. The method according to one of the preceding
2 claims, characterized by the selection of a layer thickness ratio
3 d_4/d_3 of greater than about 10.

1 60. The method according to one of the preceding claims,
2 characterized in that a second layer (5) with a thickness $d_5 = 50 -$
3 1000 nanometer is selected.

1 61. The method according to one of the preceding claims,
2 characterized in that a second layer (5) with a thickness $d_5 = 300 -$
3 - 500 nanometer is selected.

1 62. The method according to one of the preceding claims
2 in which the layer (3) to be strained is locally strained.

1 63. The method according to one of the preceding claims
2 characterized in that the layer (3) to be strained is locally
3 strained in the regions which are vertical in a plane with the
4 defect region.

1 64. The method according to one of the preceding claims
2 characterized in that the defect region (7) is produced at a
3 spacing of 500 nanometers from the layer to be relaxed.

1 65. The method according to one of the preceding claims
2 characterized in that the defect region (7) is arranged at a
3 spacing of 50 to 100 nanometers above the layer (4) arranged upon
4 the layer (3) to be strained.

1 66. The method according to one of the preceding claims
2 characterized in that the first and second layers (4, 5; 11, 12,
3 13) after producing the strained layer (9) or after producing a
4 strained region, are removed.

1 67. The method according to one of the preceding claims
2 in which etching, especially wet chemical material-selective
3 etching, is used.

1 68. The method according to one of the preceding claims
2 in which etched trenches (15) are produced in the depth of the
3 layers (2, 3, 4, 5, 9, 11, 12, 13).

1 69. The method according to one of the preceding claims
2 characterized in that after producing the etched trenches (15) a
3 relaxation of the layer (4; 11) or a further layer, especially by a

4 thermal treatment, is carried out.

1 70. The method according to one of the preceding claims
2 characterized in that the trenches (15) are filled with insulating
3 material to produce shallow trench insulation (14).

1 71. The method according to one of the preceding claims
2 characterized in that at least one further thermal treatment is
3 carried out for relaxation of one or more layers.

1 72. The method according to one of the preceding claims
2 characterized in that a strained layer (9) and/or an unstrained
3 layer (3) are produced with a surface roughness of less than 1
4 nanometer.

1 73. The method according to one of the preceding claims
2 characterized in that a surface roughness of layers (3, 9) is
3 further reduced by the growth of a thermal oxide thereon.

1 74. The method according to one of the preceding claims
2 characterized in that on a strained region of the layer (9) and n-

3 and/or p- MOSFET is produced.

1 75. The method according to one of the preceding claims
2 characterized in that a further epitactic layer (10) comprising
3 silicon or silicon/germanium (Si-Ge) or an Si-Ge-C layer or a
4 germanium layer are deposited.

1 76. The method according to one of the preceding claims
2 characterized in that on a strained silicon-germanium (Si-Ge)
3 region (11) p-MOSFETs are produced as further epitactic layers or
4 as nonrelaxed layers structures.

1 77. The method according to one of the preceding claims
2 characterized in that on unstrained region (3) of the layer 3 to be
3 strained, bipolar transistors are processed.

1 78. The method according to one of the preceding claims
2 characterized in that for producing a bipolar transistor, a
3 silicon-germanium layer is applied.

1 79. The method of producing a layer structure comprising

2 a plurality of strained layers, characterized in that one or more
3 of the method steps in claims 1 - 78 is carried out a plurality of
4 times.

1 80. A layer structure comprising a layer (9, 3) on a
2 substrate (1, 2), characterized in that the layer (9, 3) is partly
3 strained.

1 81. The layer structure according to the preceding claim
2 characterized in that the strained region (9) of the layer (9, 3)
3 lies in a plane and is coplanar with and adjacent the unstrained
4 region (3) of the layer (9, 3).

1 82. The layer structure according to one of the
2 preceding claims 80 or 81 in which the at least one relaxed layer
3 (4, 11) is arranged above and/or below at least one strained layer
4 (9).

1 83. The layer structure according to one of the
2 preceding claims 80 - 82 characterized in that without the
3 formation of a step between them, a strained region and an

4 unstrained region of the same layer material lie in coplanar
5 relationship in a plane of the layer.

1 84. The layer structure according to one of the
2 preceding claims 80 - 83 characterized by an insulator (2) as the
3 substrate.

1 85. The layer structure according to one of the
2 preceding claims 80 - 84 characterized in that strain layer (9)
3 and/or the unstrained layer (3) have a defect density smaller than
4 10^7 cm^{-2} .

1 86. The layer structure according to one of the
2 preceding claims 80 - 85, characterized in that the strained layer
3 (9) and/or the unstrained layer (3) have a defect density smaller
4 than 10^5 cm^{-2} .

1 87. The layer structure according to one of the
2 preceding claims 80 - 86, characterized in that at least one
3 strained layer (9) and/or at least one unstrained layer (3) have a
4 surface roughness of less than 1 nanometer.

1 88. The layer structure according to one of the
2 preceding claims 80 - 87, characterized in that on the strained
3 layer (9) and/or the unstrained layer (3) further epitactic layers
4 (10, 11, 12, 22) are arranged.

1 89. The layer structure according to one of the
2 preceding claims 80 - 88, characterized in that in the strained
3 region (9) an insulation region (14) is located.

1 90. An electronic component comprised of a layer
2 structure according to one of the preceding claims 80 - 89.

1 91. A transistor especially a modulated doped field
2 effect transistor (MODFET) or a metal oxide semiconductor field
3 effect transistor (MOSFET) forms the component according to claim
4 90.

1 92. A fully depleted MOSFET as the component according
2 to claim 90.

1 93. A tunnel diode, especially a silicon germanium (Si-
2 Ge) tunnel diode as the component according to claim 90.

1 94. A silicon-germanium quantum cascade laser as the
2 component according to claim 90.

1 95. A photo detector as the component according to claim
2 90.

1 96. A light emitting diode as the component according to
2 claim 90.